

6. What operational guidelines should be considered for implementation of planned cockpit rest in long-haul operations?
7. Would planned cockpit rest be an improvement over the current situation of uncontrolled spontaneous napping in nonaugmented long-haul flying?

3.0 METHODS

3.1 Study Design Overview

This study involved regularly scheduled transpacific flights with nonaugmented B-747 three-person crews. Volunteer pilots were randomly assigned to one of two study groups. The rest group (RG) was allowed a 40 min. opportunity to sleep during the overwater cruise portion of flight. On a rotating basis, individual crewmembers were allowed to nap in their cockpit seat. The no-rest group (NRG) was not offered a nap opportunity, and instead performed their usual operational activities throughout the flight.

Before the study began, briefings regarding the operational and scientific goals of the project were held with the Federal Aviation Administration (FAA), the National Transportation Safety Board (NTSB), airline management, and pilot union officials. The FAA co-sponsored the project and provided crucial support through its sanction for cockpit rest. It was vital that all concerned parties be informed and support the project. The two airlines approached agreed to participate in the study. Each airline's participation was dependent on the availability of specific transpacific trip schedules and volunteer pilots.

3.2 Subjects

All subjects were line pilots who volunteered to participate in the study. The data in this report were based on pilots flying the regularly scheduled transpacific trip outlined in the next subsection. After this specific schedule had been selected, the trip was marked in subsequent bid packages to indicate that pilots bidding this trip would be contacted by NASA researchers for volunteer participation in a fatigue study. Once pilots were assigned to the trip, a NASA principal investigator contacted them regarding the project. Initial contact was by letter and telephone with a description of the ongoing NASA program to study crew fatigue and jet lag and an outline of the proposed study. The specific requirements of participation were described in detail and questions or concerns were addressed thoroughly. It was clearly indicated that involvement would be completely confidential, that the FAA and their airline had sanctioned the cockpit rest, and that their participation was completely voluntary at all times, including once they had begun the protocol. Therefore, volunteers were informed that they could withdraw at any point in the study. No financial or other remuneration was offered or provided for participation. If pilots volunteered, then information packets (written and video materials), questionnaires (e.g., logbooks), and some equipment (e.g., actigraphs) were given to them.

It has been the general policy of this NASA Fatigue Countermeasures Program to provide complete confidentiality and anonymity for all pilots participating in studies. This effect required additional sanctions and guarantees by the FAA and participating airlines for pilots in the rest group to be allowed a cockpit rest period. Participating volunteers were assigned an identification code that was used for all data collected. Only identification numbers were associated with any identifiable component of the project.

3.3 Trip Characteristics

The specific trip pattern studied was chosen to meet certain scientific and operational conditions. These conditions included multiple transpacific crossings, some equal groupings of day and night flights, comparable flight lengths, regularly scheduled, nonaugmented crews, low

workload (cruise) portions of flight over water, and a trip of sufficient length that fatigue would be a factor.

The middle four legs of an eight-leg regularly scheduled trip pattern were studied. The trip schedule is outlined in table 1, where asterisks indicate the departure and destination airports of the four study legs. The overall trip schedule and study legs are shown geographically in figure 1.

Table 1. Study trip schedule

Trip Leg	Study Leg	From	To	Flight Time	Duty Time	L/O Time
1		SEA	NRT	9.9	12.9	26.4
2		NRT	HNL	6.7	8.4	22.2
3	1	HNL*	OSA*	9.5	10.6	29.4
4	2	OSA*	HNL*	6.9	9.1	25.4
5	3	HNL*	NRT*	8.9	9.9	24.3
6	4	NRT*	LAX*	9.7	11.7	25.0
7		LAX	SEL	13.8	14.8	19.3
8		SEL	SEA	9.8	11.6	-----

Note: (L/O = layover; SEA = Seattle; NRT = Narita; HNL = Honolulu; OSA = Osaka; LAX = Los Angeles; SEL = Seoul)

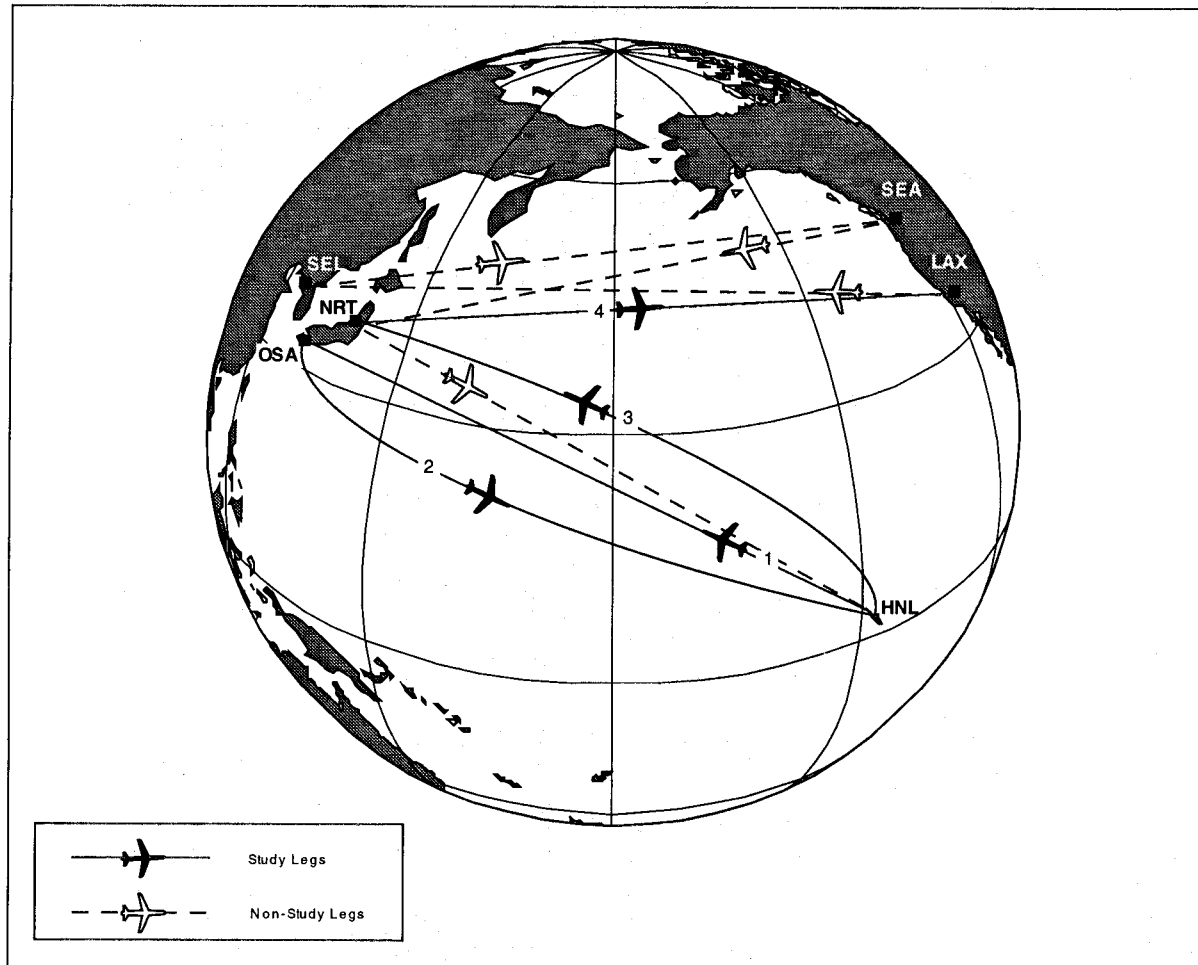


Figure 1. Geographic portrayal of overall trip schedule and study legs.

The entire trip schedule spanned 12 days. The study legs were balanced: two daytime westward legs (study legs 1, 3; trip legs 3, 5) and two nighttime eastward legs (study legs 2, 4; trip legs 4, 6).

Figure 2 shows the cockpit rest study trip profile in greater detail.

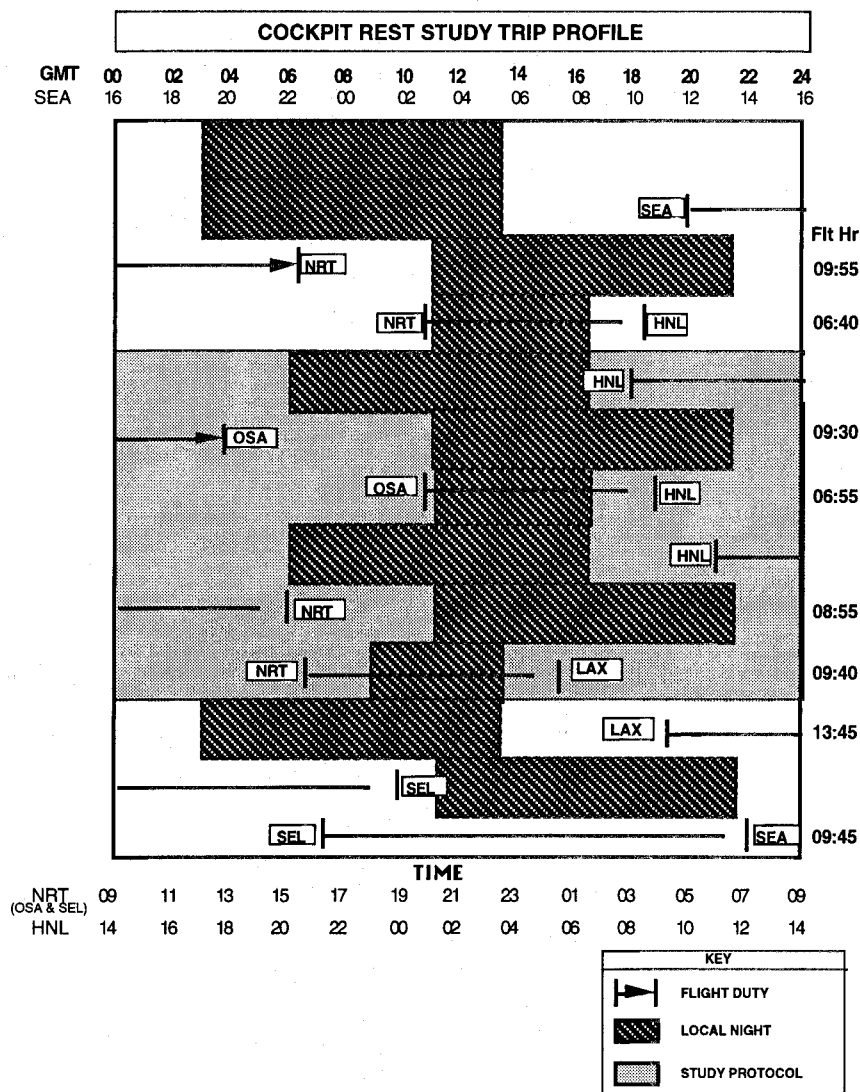


Figure 2. Detailed version of the cockpit rest study trip profile.

3.4 Research Personnel

There were two NASA observers/researchers to implement the procedures and collect data on each trip. Therefore, a two-person team of NASA researchers was assigned to accompany each volunteer crew throughout the four flight legs. The team always had one researcher familiar with aviation and able to take detailed operational notes and one able to conduct the physiological recordings. Once in the field, the NASA team had responsibility for maintaining the integrity of the protocol and determining appropriate responses to unforeseen occurrences. None of the NASA researchers was employed or affiliated with the participating airlines or the FAA. Many others

were also involved in the diverse and complex tasks required to conduct this study. Their roles are highlighted in the preface.

3.5 Measures

Multiple measures (i.e., physiological, behavioral, and subjective) were used to determine the effectiveness of the cockpit rest period in improving subsequent crew performance and alertness. Specific measures were chosen to evaluate the fatigue, sleep loss, sleepiness, and performance associated with long-haul flight operations.

3.5.1 Physiological Measures

A variety of physiological measures was used to discriminate sleep and wakefulness and to measure physiological alertness/sleepiness.

Physiological Recording of Sleep and Wakefulness

The planned cockpit rest period provided an opportunity for a nap, the primary countermeasure evaluated in this study. A crucial question was whether, given the opportunity, pilots would actually sleep during the rest period. Generally, individuals do not accurately describe their sleep. Laboratory studies have demonstrated that normal, healthy individuals, as well as sleep disordered patients, can give subjective reports of their sleep very discrepant from physiological measures of sleep and wakefulness (refs. 21-23). The general trend is that people subjectively report more wakefulness than demonstrated by objective physiological measures of sleep and wakefulness; that is, people get more sleep than they realize. Usually, individuals report taking a longer time to fall asleep and less total sleep time than indicated by physiological data. This known discrepancy between the subjective experience of sleep and physiological sleep was a very important consideration in this study. It was crucial to determine the quantity and quality of physiological sleep that occurred during the rest period, as well as the subjective description of the nap. Therefore, ambulatory physiological recordings were used to determine if crewmembers fell asleep, how long it took them to fall asleep, the total amount of sleep, and the type of sleep obtained.

Polysomnography (PSG) involves the continuous measurement of physiological variables that are used to distinguish the states and stages of sleep (refs. 24, 25). Standard sleep-laboratory-based PSG for differentiation of sleep and wakefulness involves recording brain waves activity (electroencephalogram or EEG), eye movements (electrooculogram or EOG), and muscle activity (electromyogram or EMG). These physiological variables allow the differentiation of sleep and wakefulness and the two distinct states of sleep: NREM (pronounced non-REM) and REM (rapid-eye-movement). NREM sleep is further divided into four stages with stages 1 and 2 being lighter sleep and stages 3 and 4 deeper sleep (slow-wave sleep). REM sleep is characterized by high brain activity, bursts of rapid-eye-movements, and muscle suppression; it is associated with dreaming. NREM and REM occur in a regular cycle throughout sleep.

In this study, only noninvasive procedures were used for attaching electrodes to the scalp and face of the test subjects to record these physiological variables. Brain activity was recorded from central positions on the scalp (C₃/A₂ and C₄/A₁) and eye movements were recorded from placements on the outside of the eyes (outer canthi) (ROC/A₁ and LOC/A₂). Muscle activity was not recorded in this study because (1) it can create artifacts (generated by talking, eating, etc.) that can obscure the recording; (2) the visibility of chin electrodes might have inhibited crewmembers from their usual movement outside the cockpit; and (3) although low muscle activity differentiates REM sleep, the rest period was considered too brief for the occurrence of REM. All of the PSG methods followed standardized and accepted procedures (refs. 24, 26).

These physiological variables were recorded during regular flight operations using an Oxford Medilog 9000-II ambulatory recorder (Oxford Medical Limited, Abingdon, Oxon, England). This small, lightweight (550-g), battery-operated system allowed continuous recording of brain and eye

movement activity onto a standard C-120 cassette tape. For this study, the physiological data from the planned 40 min. control period (RG) and control period (NRG) was played back through a polygraph to create a paper record, as if the data had been collected in a sleep laboratory. The 40 min. paper records for the RG control and NRG control periods were then visually scored according to standardized and accepted criteria (ref. 25).

Physiological Alertness/Sleepiness

If pilots obtained sleep during the rest period, how would this nap affect subsequent physiological alertness? There is a laboratory-based test, now widely used for the objective quantification of physiological sleepiness (i.e., the Multiple Sleep Latency Test or MSLT) (ref. 27). The laboratory provides a controlled and standardized environment to unmask underlying physiological sleepiness as measured objectively by the speed of falling asleep. However, there is an increasing interest in measuring physiological sleepiness in ambulatory individuals during regular operations (e.g., shift workers, train operators, truck drivers, and pilots) (for a discussion of this issue, see refs. 28-30). This requirement obviously presents a different set of circumstances than the laboratory environment and the use of some alternative approaches (e.g., portable physiological recorders).

Brain (EEG) and eye movement (EOG) activity can reflect the subtle ways that physiological alertness fluctuates. It is often difficult to discriminate and subjectively report these subtle physiological changes, though they can be measured, quantified, and related to performance. There have been a number of studies examining physiological sleepiness with measures of EEG and EOG activity in a variety of operational settings; some examples are train operators (refs. 31, 32); car drivers (refs. 33); shift workers (refs. 34, 35); and military operations (ref. 36). Also, several approaches have been used to analyze the EEG and EOG data, including automatic/computer methods (e.g., period-amplitude analysis or spectral analysis; for examples see refs. 37, 38) and visual evaluation (e.g., ref. 36).

These studies, and others, have generally found that three variables emerge that are associated with physiological alertness/sleepiness: alpha (8-12 Hz) and theta (3-7 Hz) EEG activity and SEMs in the EOG (refs. 28, 30, 37, 38). EEG alpha activity is considered quiet, relaxed wakefulness with eyes closed, appearing just prior to sleep onset and usually blocked when the eyes are opened (refs. 24, 25). EEG theta activity is acknowledged as light sleep, NREM stage 1 (refs. 24, 25). Slow-rolling eye movements (SEMs) are associated with the transition to sleep and may reflect the perceptual disengagement from the environment that characterizes sleep onset (refs. 24, 25).

Torsvall and Akerstedt provide one example of how these variables have been related to physiological sleepiness in active individuals (ref. 3). Using Medilog recorders, EEG and EOG data were collected during a monotonous 45 min. visual vigilance task. Spectral quantification of the EEG demonstrated clear, homogeneous patterns related to accurate performance, errors, and periods of "dozing off" (considered extreme behavioral sleepiness). EEG power density in the alpha, theta, and delta bands was highest just before dozing off periods and lowest during "hits" (i.e., accurate performance). The alpha power increased by a factor of 6, and theta power increased by a factor of 3, from scoring a hit to dozing off. The occurrence of SEMs also increased significantly before dozing off and was associated with decreased performance. This laboratory-controlled study of active individuals demonstrated that there was a relationship between physiological sleepiness and behavioral performance reflected in systematic changes in EEG and EOG activity. Therefore, quantification of EEG frequency and EOG changes associated with increased physiological sleepiness may identify periods of vulnerability when there is an increased risk of lapses in vigilance and performance, possibly without subjective awareness. These brief and subtle changes in brain and eye activity are especially important in light of previous data that suggest that the subjective reports by pilots of alertness/sleepiness are poorly related to their level of physiological sleepiness (refs. 39, 40).

Returning to the question originally posed: If the pilots were able to sleep during the rest period, was this nap associated with the subsequent maintenance or improvement in physiological alertness? The Medilog recorder provided continuous EEG and EOG data that were examined for changes related to physiological alertness during critical phases of operation. The initial analysis

focused on the period 1 hr. before top of descent (TOD) through descent and landing. This represented about the last 90 min. of flight. A microevent analysis of this 90 min. period identified specific EEG and EOG changes that occurred at anytime during this period. Based on the scientific research previously cited, the individual occurrences of three specific physiological events associated with increased sleepiness were scored: (1) EEG alpha activity (8-12 Hz), (2) EEG theta activity (3-7 Hz), and (3) EOG slow-rolling eye movements (SEMs; $> 100 \mu\text{V}$ amplitude, $> 1\text{-sec.}$ duration) (refs. 24, 28, 29).

The duration of each microevent occurrence was scored according to these three time bins: (1) 5-10 sec., (2) 11-15 sec., and (3) >15 sec. The events were analyzed visually on a screen by a research assistant with over 6 years experience scoring sleep. Subsequent analyses are planned to compare visual scoring of microevents to spectral analysis and to examine other phases of flight.

The term "microsleep" is often used to describe the brief occurrence of EEG theta activity that can be associated with a performance lapse (e.g., ref. 6). However, as indicated by the scientific literature previously described, EEG alpha and SEMs also increase significantly before and during performance lapses. Therefore, the term adopted for the approach described here was "microevent." These EEG (alpha and theta) and EOG (SEMs) microevents are associated with physiological sleepiness and have been related to decreased behavioral performance (see previous citations). Relative to the use of the more popular term, microsleep, microevents reflect arousal transitions and attention lability (e.g., eye closures) rather than states per se. Therefore, this intensive analysis identified the occurrence of EEG and EOG microevents, lasting 5 sec. or longer, associated with increased physiological sleepiness during the last 90 min. of flight for both the NRG and RG.

Another physiological measure of pilot sleepiness was determined from the rest period data. Physiological sleepiness (sleep tendency) has been operationally defined as the speed of falling asleep, that is, a sleepy individual falls asleep quickly (short sleep latency) and alert individuals take a long time to fall asleep or do not fall asleep (long sleep latency) (refs. 21, 27). Therefore, not only is the occurrence of sleep during the rest period important, but the speed at which crewmembers fall asleep can be used as an indication of their level of physiological sleepiness.

On initial data collection trials, when standard Medilog 9000 recorders were used in the cockpit, a 10 Hz noise was recorded that obscured the biological signals. Avoiding all the potential sources of electrical noise in the cockpit appeared impossible, and an internal 10 Hz filter would have removed EEG frequencies crucial to the determination of sleep and wakefulness. Systematic troubleshooting procedures demonstrated that the interference was created by 400 Hz electrical activity prevalent in the cockpit and that it resulted in an "aliased" 10 Hz activity. A new Medilog 9000-II recorder, superseding the 9000, was available with improved common mode-rejection and enhanced screen drive frequencies up to the 400 Hz range. Oxford engineers modified the 9000-II further with input filters configured for 40 dB rejection of 400 Hz that provided a bandwidth of 0.5 to 40 Hz. The modifications of the 9000-II resulted in artifact-free physiological recordings in the cockpit environment (ref. 41).

A portable sleep laboratory was created with all the necessary equipment and supplies to conduct the ambulatory physiological recordings with the Medilog 9000-II recorders. During the data collection trips, the NASA research team organized the equipment and supplies in one hotel room where the electrode application took place before departure for the airport. Most electrodes were applied in the hotel room, especially those that required chemicals not allowed on the flight deck. The leads were bundled up and placed on the top of the head underneath the uniform hat to minimize the reactions of others. Generally, the hook-up procedure required about 12-15 min. per pilot to complete. Once on the flight deck, the remaining electrodes were placed and the physiological recording initiated. Once the recordings were initiated, the Medilog was stored in the pocket on the back of each pilot's seat. When leaving the cockpit, the pilot would usually wear a uniform hat, sometimes a jacket, and use a shoulder strap to carry the Medilog. The physiological recordings were continued throughout the flight. After landing and postflight duties, all of the electrodes, except the EEG scalp placements, were removed in the cockpit. The last EEG electrodes were removed at the layover hotel.

3.5.2 Performance: Sustained Attention/Reaction Time

In humans, performance probes are commonly used to evaluate the functional capability of persons who are either experiencing sleep loss or who are suspected of having occupationally induced fatigue due to their work-rest schedules. These tasks are an essential means for obtaining an estimate of best effort over time. When used in field studies, they provide an index of the severity of functional impairment present during a field trial without taking the costly approach of using more dramatic or very infrequent field outcome variables (e.g., crashes or near misses). Thus, performance probes serve to: (1) identify zones of vulnerability in sleepy and fatigued persons; (2) provide a common metric by which field data can be calibrated against laboratory data; and (3) give meaning to the consequences of physiological and subjective changes in flight crews.

There is ample evidence that fatigue resulting from sleep loss, acute or chronic, as well as circadian rhythm disturbance results in diminished performance capability (refs. 2, 6, 42-46). The performance test selected for this field experiment had to meet four major criteria:

1. Since the primary hypothesis of the experiment was that planned cockpit rest would diminish the effects of fatigue in long-haul crews, the task had to be well documented in laboratory studies of sleep loss, napping, and circadian rhythms to be sensitive even to subtle shifts in sleepiness/alertness.
2. The task had to reflect variability caused by sleepiness in a basic human performance capability, such as attention, which is a fundamental feature of cognitive and flight operations tasks.
3. Since the experiment required repeated performance measurements before, during, and following flight operations, a task was required that could be carried out at each time point, rather than only during flight or only pre- and postflight. This repeated assessment meant that the performance probe also had to be generally devoid of practice or learning effects.
4. The performance task selected had to be sufficiently brief to avoid interfering with actual flight operations and routine pre- and postflight activities (i.e., the real-world scenario), yet it had to yield performance parameters that clearly were informative about the nature of the change in the central nervous system (CNS) associated with fatigue due to sleep loss, circadian rhythm disturbance, and night flights.

Given these criteria, a highly reliable and well-validated performance probe was selected over an approach that relied on flight operations parameters or that utilized complex cognitive tasks. The former was rejected because there is as yet no reliable scientific data base on the extent to which fatigue alters performance of specific flight operations tasks. In addition, among other problems of standardization in a field study, operations tasks can only be measured during flights in actual real world scenarios (not pre- or postflight). Hence, the use of flight-operations tasks in this experiment was neither preferred nor practical, despite their face validity. The repeated-measures nature of the design also precluded the use of many complex cognitive tasks (based on laboratory research), which are subject to major secondary variance from practice effects (intrasubject variability) and individual differences (intersubject variability).

The performance probe chosen for this study was a psychomotor vigilance task (PVT) that requires sustained attention and rapid reaction time to an intermittent light stimulus for a 10 min. period. It meets the four major criteria listed above, and attentional capacity as assessed by this task is operationally significant, since attention is fundamental to many tasks and most information exchange. Moreover, there are extensive data showing that high-signal-load reaction time tests are sensitive to total sleep loss (refs. 13, 47-53), to partial sleep loss (refs. 54, 55), and to circadian variation in performance efficiency (refs. 56, 57).

PVT data were recorded as sine waves on an audio tape in a portable device that consists of a modified, battery-powered cassette player (9 by 4 by 2 inches). It had a light-emitting diode (LED) counter window next to a small, white microswitch button on the face of the recorder. A stimulus, red digits "000," appeared in the window and began increasing in milliseconds. The pilot sat with the PVT positioned comfortably in his or her lap, finger poised on the push button, and watched

the blank window. The pilot was instructed to push down on the button as soon as the stimulus lights appeared, with an emphasis on the speed of response. When the button was pressed, the running millisecond counter stopped and revealed the response time. The number was displayed for 1.5 sec., then the display went blank and there was a variable, 1-to-10-sec. interval before the onset of the next stimulus. Each pilot completed the PVT five times over the course of each study flight leg. Each trial was administered for 10 min.: (1) preflight in the hotel; (2) after top of climb and before the scheduled rest or control period; (3) closely following the identified rest or control period; (4) just before TOD; and (5) postflight in the hotel.

Over the past 10 years, Dinges focused on the precise nature of performance impairment engendered by sleep loss and shifts in work-rest schedules (refs. 6, 58). Using reaction time as the basic response mode, Dinges has developed a data processing system of sustained attention on the PVT that is very sensitive to fatigue resulting from sleep loss, as well as to circadian variation and desynchronization. These methods go beyond the usual analytical approaches applied to reaction time and sustained attention tasks (ref. 59). The completed cassette data tapes were analyzed by the University of Pennsylvania laboratory. Data reduction through the software system resulted in four measures of performance for each 10 min. PVT trial: (1) response slowing (median reaction time [RT] in a trial); (2) response lapsing (mean of the slowest 10% RTs in a trial); (3) optimum responding (mean of the fastest 10% RTs in a trial); and (4) vigilance decrement (slope and y-intercept of a least-squares regression equation fitted to the 1 min. changes across the 10 min. trial) (refs. 13, 50, 59, 60). Using this analytical approach, the PVT has been found to be more sensitive to sleep loss, circadian phase, and the beneficial effects of naps on alertness, than an array of short-duration cognitive tests that are typically used in laboratory studies of circadian rhythms (ref. 12).

3.5.3 Actigraphy: Motor/Physical Activity

Actigraphy is a relatively new ambulatory technique that uses a device to objectively record circadian rest/activity patterns over many days (refs. 61, 62). The actigraph provides information that complements physiological data and subjective self-report measures. It is a cost-effective means for collecting continuous, objective behavioral data in operational settings without interfering with the subject's usual activity.

The actigraph device (wrist activity monitor or WAM) used in this study was a lightweight (3 oz) microprocessor with an internal piezoelectric sensor, housed in a small rectangular box (6 by 4 by 1.5 cm) that straps to the nondominant wrist (Ambulatory Monitoring, Inc., Ardsley, New York). The unit has no external wires and can be comfortably worn for many days (removed only for bathing). The actigraph stores the number of movements recorded by the piezoelectric sensor into discrete bins. The time-base can be preset from 7 sec. to 20 min.; with the smaller bin length, the device will continuously record data for less total time before filling its memory. In this study, a 2 min. bin length allowed continuous data collection for 16 days. By use of an interface device, the data were transferred from the actigraph to a microcomputer as an ASCII file. The file contained the day and time (to the minute) of each consecutive bin, as well as the number of movements accumulated in each bin. Both a histogram printout of the record and a numerical printout were derived. Computer analysis of the actigraph data yielded information relevant to the temporal placement of sleep periods, to the amount of wake activity, the duration of sleep periods on layover, and the amount of movement during sleep.

A WAM was sent to all volunteers before they left home. It was worn continuously 3 days before leaving home, throughout the entire 12-day trip schedule, and for up to 3 days after arriving home.

3.5.4 Logbook

The NASA Fatigue Countermeasures Program has accumulated extensive experience with a Pilot's Daily Logbook to collect subjective, self-report data in a variety of studies (for examples, see refs. 3, 36). The logbook is divided into two basic sections: (1) a daily log and (2) a mood

checklist. The daily log provides space for recording wake-up time, sleep patterns and quality, exercise, duty time, layovers, naps, meals and beverages, smoking behavior, medication use, and physical symptoms. Included is a 10 cm analog scale where pilots subjectively rate their level of waking alertness from most drowsy to most alert. The mood checklist contains 26 adjectives that are rated from 0 = not at all to 4 = extremely. The Pilot's Daily Log provides information on 24 hr. patterns of activity, layover sleep, daily food intake, etc., to give an overall record of a pilot's activities on a trip.

The Pilot's Daily Log was sent to all volunteers before they left home. It was completed continuously, on a daily basis, 3 days before leaving home, throughout the entire 12-day trip schedule, and for 3 days after arriving home.

3.5.5 Subjective Mood/Alertness Ratings

The same 10 cm analog alertness scale and the 26-item mood checklist in the Pilot's Daily Log were to be completed and administered hourly during each study flight leg. This checklist contained self-report adjectives to characterize mood and alertness.

3.5.6 Observer's Log

One member of the NASA research team (usually an individual holding at least a private pilot license) maintained an Observer's Log throughout each study flight leg. This log was used to record information on flight activities and conditions, such as turbulence, lighting, block and flight times, takeoff and landing events, equipment problems, meals, and other noteworthy occurrences during flights. Also, the NASA research team maintained a time-line during each study flight leg to document when study procedures actually occurred and to record the flow of the protocol.

3.5.7 Operational Problem

A gross-weight takeoff problem was administered immediately following the identified nap or control period. It was intended to provide information on cognitive functioning and the potential effects of sleep inertia (intense sleepiness experienced following an awakening from deep sleep) after the nap.

3.5.8 NASA Background Questionnaire

The NASA Background Questionnaire was designed in June 1982 for use in studies of human performance in long- and short-haul flight operations (ref. 63). It contains 215 questions in a variety of formats and usually takes less than 1 hr. to complete. The inventory examines some of the factors involved in pilot fatigue, including (as stated in the instructions to pilot participants) sleep-rest cycles, nutrition, life-style, attitudes toward work, and certain personality profiles. Sections of the inventory assess the following: basic demographics, including flight experience; general health status and activities; home sleep quantity, quality, and timing; and self-ratings of personal characteristics.

The background questionnaire was sent to pilot volunteers as part of the initial information packet prior to field data collection. It was completed and returned to the NASA research team that accompanied the crew during the study flight legs.

3.6 Procedures

To initiate the field data collection component of the study, volunteer pilots were met by the NASA research team in Honolulu the day before the first study-trip leg. It was at this time that the crews were informed about their random placement into either the no-rest control group or the rest group. No information prior to this time indicated whether a crew would be allowed the rest opportunity. This was done to minimize any alterations of pilots' usual trip activities, sleep/wake schedule, etc., before the study legs. An orientation meeting with the crewmembers was used to describe the physiological recording procedures, demonstrate the PVT and other study measures, discuss specifics of the protocol, and answer any questions.

The overall cockpit rest protocol is shown in figure 3. The first line shows the general period of study, including days at home, flights, and home post-trip. The second line portrays the timeline for the protocol during each study flight. It indicates the placement of the three rest periods in the middle portion of the flight. Finally, the third line provides a more detailed view of the approximately 60 min. identified as the planned rest/control period.

3.6.1 Cockpit Rest Guidelines

The following guidelines were used for all cockpit rest opportunities. They were established as a first attempt to structure procedures for planned cockpit rest periods.

1. Soon after top of climb (TOC), a specific rest period (see fig. 3: rest period a, b, or c) was chosen by each crewmember. This constitutes a major aspect of the nap: it was planned and each crewmember knew generally when a rest opportunity would occur. The landing pilot had first choice, the nonlanding pilot had second choice, and the flight engineer had third choice. As part of the study, the captains agreed that the landing pilot would have priority for choice of rest period.
2. The rest periods were scheduled during cruise overwater, which is a low-workload phase of flight.
3. The rest periods were scheduled for three consecutive 1 hr. periods during cruise.
4. One crewmember was scheduled to rest at a time while the other pilots maintained flight operations. The other crewmembers rotated on the prearranged schedule.
5. The actual rest opportunity was divided into three phases: (1) a 3 min. preparation, which involved any debriefing, completion of tasks in progress, getting comfortable in the cockpit seat, etc.; (2) a 40 min. rest opportunity (pilots were offered the use of eye shades, ear plugs, and an inflatable neck pillow); (3) a 20 min. recovery period used to administer performance tests, obtain subjective ratings, etc., and to allow a return to full alertness before re-entering the operational loop.
6. Access to the cockpit was restricted during rest periods to minimize interruptions. Other crewmembers attempted to be quiet and not disruptive.
7. Rest was terminated at a predetermined time by a researcher.
8. Before resuming flight duties, the rested crewmember was briefed by the other crewmembers on flight status and any relevant flight information.

HOME + FLIGHT
(3 days) + (3 days)

STUDY FLIGHTS
(6 days)

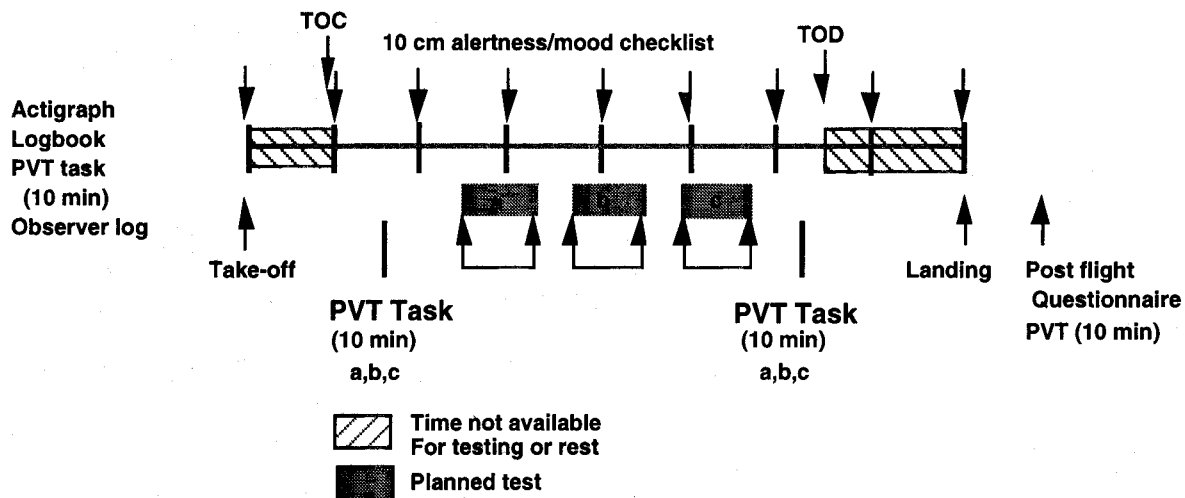
FLIGHT + HOME
(3 days)

Actigraph
NASA Background
Questionnaire
Pilot Logbook
Alertness/Mood
Checklist

Actigraph	Psychomotor
Medilog-EEG	Vigilance Task
Observer Log	Planned Rest Period
Pilot Logbook	Post Rest Questionnaire
Alertness/Mood	Operational Task
Checklist	Post Flight Questionnaire

Actigraph
Pilot Logbook
Alertness/Mood
Checklist (opt)

FLIGHT DUTY HOURS



PLANNED REST/CONTROL PERIOD

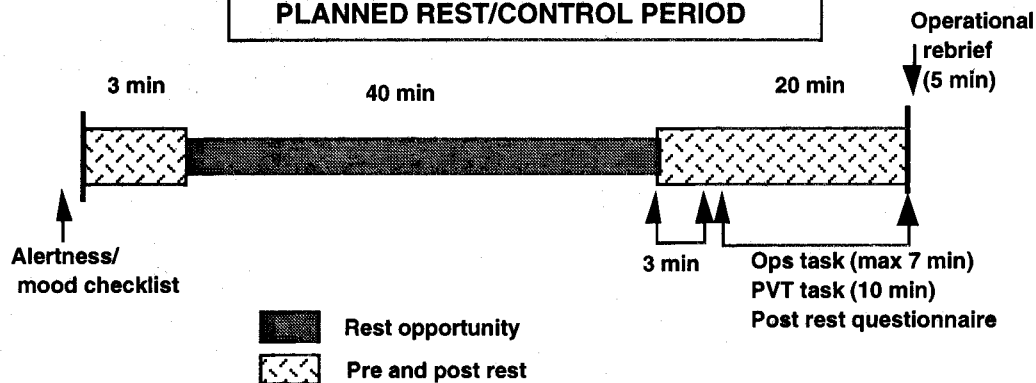


Figure 3. Overall cockpit rest study protocol.

3.6.2 Safety Procedures

The following cockpit rest period safety procedures were followed to minimize any interference with the safe operation of the aircraft.

1. Two crewmembers and two NASA observers were available while any one crewmember was resting.
2. The 20 min. recovery period was intended to allow sufficient time to return to full alertness and evaluate any concerns before re-entering the operational loop.
3. The potential for sleep inertia that might decrease performance was assessed (through inquiry by the NASA observers) before resuming flight duties.
4. A postrest update was provided on flight status and other relevant operational information before resuming flight duties.
5. The captain was to be alerted immediately upon first indication of any potential anomaly.
6. All rest periods were scheduled for completion at least 1 hr. before descent.
7. Safe, normal operation of aircraft was acknowledged as the highest priority, of course, and study procedures were not be permitted to interfere.

3.6.3 No-Rest/Control Group Procedures

Soon after TOC, the volunteer pilots in the NRG also identified a specific control period during the cruise portion of flight (see fig. 3: position a, b, or c). This served as a control period, and they followed the same procedures with a preparation time, 40 min. test period, and 20 min. "recovery" period when performance tests were administered. However, during the identified 40 min. control period, NRG pilots were instructed to continue their usual flight activities.

4.0 RESULTS

4.1 Subject Characteristics

Subject volunteer crews were randomly assigned to one of the two study groups. The NRG consisted of three crews totaling nine subjects. The RG consisted of four crews totaling 12 subjects. The mean age, mean years of experience, and sex of the volunteers are given in table 2. All of these factors were comparable between the two groups. One other field data collection trip, not included in this data set, was begun and then discontinued when rescheduling caused an alteration in the study trip schedule.

4.2 Pilot Choice of Rest Position

The procedures provided first choice of rest position to the landing pilot. Figure 4 shows the landing pilots' (for both captains and first officers [FOs]) choices for rest position a, b, or c and also the nonlanding pilots' choices. The main finding was that both captains and FOs generally chose the last rest position when they were landing the aircraft and rarely chose the first rest position. This result suggests that rather than rest early in the flight, when pilots may still be alert from layover sleep, the preferred strategy was to use the rest position later in the flight and closer to the landing.